Knight Guard, The Guardian Project

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Abstract – Knight Guard aims to create a device where a user can project themselves in case they care in danger from being kidnapped, raped, etc... To realize this, *the group* created a user-friendly device that acts as a training tool for the final product as well as the basis for the final product, that way, the user does not accidently set it off on themselves. Generally, device 1 is activated by the user which then activates device 2, which will incapacitate the attacker, and the phone application, allowing the user to be tracked from the GPS given by the phone app, on the webpage. The proper authorities will then be able to come to the scene of the crime and come to the aid of the victim.

Index terms – Bluetooth, ABS, Android, Self-Defense

I.Introduction

It is known to everybody that women, and sometimes men, have the possibility of being raped, kidnapped, etc... at any point during the day. Knight Guard wants to change that for everyone. Our sponsor set the goal on a Senior Design team consisting of Matt Lucente and Dominic Brumfield as the Electrical Engineers with Brandon Carruth and Ralph Baird as the Computer Engineers, to construct a three-device system that would act as a place holder for Knight Guard's final vision. Knight Guard was tired of all the other products on the market that simply was not good at protecting a person from harm in a non-lethal way. They also wanted the devices to be small enough to be able to hide in plain sight but still be activatable by the user. This gave the group a tough task because as the design gets smaller, it is possible that functionality may be reduced to the point of not meeting the specifications set forth. Among the hardware restrictions, the group was instructed to build a phone application to serve as a way for users to register themselves in the database and to act as a GPS point for when the device will be activated. The project was broken down into three parts; the first part was the activation of device one; the second part was a signal going from device one to device two and the phone application for activation of self-defense stand-ins; the last part is the location as well as the user inputted being shown on a website with continuously update tracking of the user's location.

Crime	**Average Occurrence per Hour**
Theft	900
Violent Crime	189
Assault	124
Robbery	66
Sexual Assault	24
Rape	12
Murder	2

Fig. 1 Average Crimes committed against women per hour, according to Women's Self-Defense Institute

Knight Guard wanted the senior design team to come up with a circuit design that would best implement a Bluetooth connection between all three devices but also have the connection be secure so that no other users can pair with the devices. Having a secure connection means there will not be any worry of somebody potentially activating the device without the original user input. To prevent this as well, Knight Guard wants the three devices to only work when they are in a maximum range of five feet. This is to ensure that the device 1 will not trigger device 2 if somehow device 2 was removed from the user. Due to the possibility of Knight Guard using the teams design as a test product, the team was instructed to create hardware housings for the devices. At the same time, they also wanted the devices to be user friendly, that way a person could be easily trained on how to use the three-device system.

II.System Components

A.Device 1

Microcontroller:

The microcontroller the team decided on is the Nordic Semiconductors NRF1822 chip as it has Bluetooth integrated into it already. Its size of six-by-six millimeters is perfect for what the team and for what Knight Guard wants as it meets the size and functionality constraints. With 256KB of flash memory and 32KB of RAM, it has plenty of room for what the project needs. Similar chips existed on the market but the team chose this one over TI or Atmel chips due to the smaller size and the built-in Bluetooth capabilities. The team decided to use the same microcontroller for device 2 for simplicity reasons. The microcontroller is designed to work in a range of 1.8V to 3.6V. As this microcontroller is going to be used in both devices, it allows the first device to still work with a smaller battery that has a max output of 3V as well as the second device which will be using a larger output with a regulator built onto the board.

Power:

To power device one, the team decided on the CR1225 Button Cell Battery as it is only twelve and a half-by-two and a half millimeters which is within the design constraints. It operates at three volts and forty-eight milliamp hours, making it perfect for the chip the team is using. The battery has a standard output of 0.1 mA current with a max output of 1 mA. Due to the chip having at least Bluetooth 4.0, it has low energy capabilities, allowing the battery to last longer.

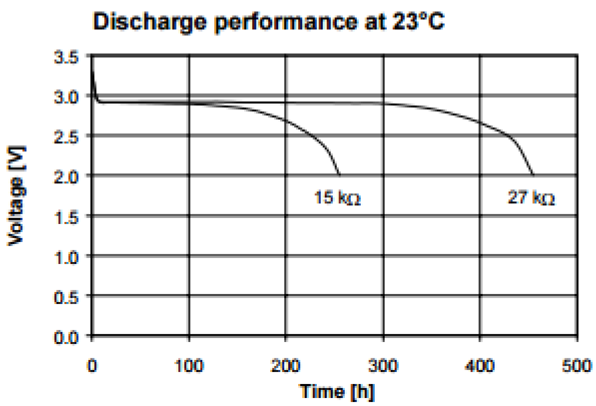


Fig. 2 Discharge rates for the CR1225 coin cell battery at room temperature with varying load amounts. Larger loads cause longer duration of battery life.

Switches:

To meet the design constraints for device 1, the team chose a mini switch that has a footprint of 2 –by-2-by-4 millimeters. Other switches were considered due to their ability to handle the voltage and current of the design, but due to their size, they were not feasible. The team did not want just one switch to activate the device, but rather, have multiple switches run in parallel. Having this configuration allows the device to be activated when a single switch is pressed but another switch can still activate it as well.

	Voltage (VDC)	Milliamps	Size (mm^3)
Mini Switch	12	50	2*2*4.4
Sliding Switch	30	200	11.6*4*12.1
Tactile Switch	24	50	6*6*10.5

Fig. 3. Comparison of switches used in the project, displaying max voltage, current that each of the switches can handle, as well at the size of the switch.

Other components:

Along with the main components that are needed for basic functionality, the chip still needs an oscillating crystal and an antenna. The oscillating crystal is mainly used to control the clock speed of the chip, meaning, it acts as a base clock for the program to function. The antenna configuration takes up the most run but it also is one of the most important parts as without it, no Bluetooth signal will be able to transmit.

Housing:

Another requirement that was imposed on the team was to come up with a hardware housing for device 1 and device 2. The housing would protect the devices from the outside elements and would be cheap to manufacture on a larger scale. The easiest and most cost-effective form of producing was chosen to be 3-D printing. Two different 3-D printing materials were considered and ultimately, the team chose to use ABS. Even though ABS is the same price as PLA, ABS has a higher temperature threshold for warping.

	Tensile Strength	Toughness	Heat Deflection Temperature
ABS	33 MPa (4,700 psi)	106 J/m	204°F
PLA	50 MPa (7,250 psi)	80 J/m	150°F

Fig. 4. Comparison of the strength and temperature that causes warping with the materials considered for the casings of device 1 and device 2

Notice how the Heat Deflection Temperature on PLA is 150°F, this temperature is achievable naturally on earth. To achieve this temperature, however, the material would have to be on the dash on the inside of a car during a hot summer day in a desert region.

3D printing:

The team decided to use 3-D printing as the bases for the hardware housing as it was the cheapest and easiest to implement. For an object to be 3-D printed, a user must create the desired object using modeling software such as

SolidWorks. After the user has created the file, they must save the file as a STL file so it may be ready for the printer.

After the file has been sent to the printer, the user would have to determine how the printer would print. This means that the user can determine the strength, quality, cost, and speed of the print based on the infill and layer height desired. This is all shown on the table below.

REQUIREMENTS				SETTINGS	
Strength	Quality	Low Cost	Speed	Infill %	Layer height
✖				100	0.25
	✖			10	0.1
		✖		10	0.1
			✖	10	0.3
✖	✖			90	0.15
✖		✖		70	0.2
✖			✖	90	0.3
	✖	✖		10	0.1
	✖		✖	10	0.15
		✖	✖	10	0.3
✖	✖	✖		80	0.15
✖	✖		✖	90	0.2
✖		✖	✖	70	0.3
	✖	✖	✖	10	0.15
✖	✖	✖	✖	70	0.2

Fig. 5. Optimal settings for 3D printing to achieve specific requirements of the casing

B.Device 2

Battery:

To power device 2, the team decided on the LiPo Single Cell Battery which has a footprint of four –by-twelve-by-thirty millimeters. Even though the battery is bigger, it is necessary as it must power more devices in the device. Running at 3.7 volts and 105milliamp hours, it will be able to stay on for roughly one whole business day, which is within the design specifications. It was chosen over the NiCad or Alkaline battery types due to their size and charging circuit complexity.

NiMH Vs Lipo	
Has Standardized sizes	Non-standard sizes: can be as small as manufacturer wants
Uses more pulsed charging techniques	Uses continuous charging
Non-constant voltage during charge	Maintains constant voltage and current to balance cells
Harder, safer outer shell	More volatile chemistry, can combust if short
Uses temperature sensor to stop current in case of a short	Uses protection circuit to prevent shorts
Must be fully discharged to maintain lifetime of the battery	Has no memory effect

Fig. 6. Comparison of attributes of rechargeable batteries used in the second device

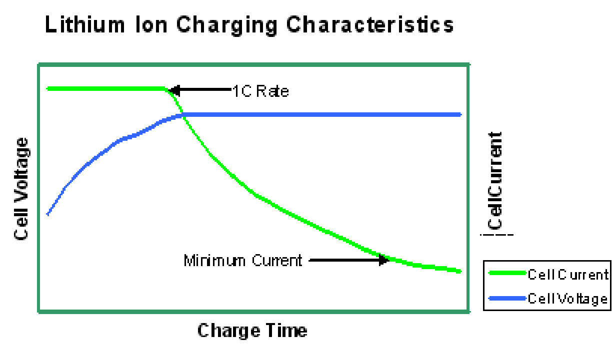


Fig. 7. Charging characteristics of Lithium based rechargeable batteries

Defense:

A future customer is going to need to try out the device network before they can the real thing because there could be an instance where they accidently set it off. To get around this, the team decided to use a buzzer and a led to simulate the activation of device 2. The buzzer the team decided on is a Magnetic Buzzer that operates on 2.5 volts which is within the range of the battery and at 9mm in diameter, is small enough to be implemented on in the design. With a frequency of 2.3kHz, it is like the loudness as standing on a busy street corner which can be heard by almost everyone.

Housing:

The creation of the housing for device 2 is the same method as for device 1 but with some changes. The device 2 housing must be larger by default due to the nature of the circuit with all the other components with it. The design of the second device allows for holes to propagate the buzzer sound as well as allow the micro-USB to get to the PCB for the charging circuit that is added to the device.

III. Device 1 Usability

The primary use for the first device is to act as an activation beacon for the other two points of the overall project. The design of the device is to be as small as possible so that it can be easily hidden, if a user were to be attacked. The device with the casing should be able to easily fit in the palm of the user's hand. The PCB design for the device is 19.7 mm X 16.15mm which makes the size comparable to a standard coin, keeping the design small enough to fit within the constraints of wanting the device to be hidden easily.

The design for the device is only a power source, the microcontroller, and the antenna components. This keeps the device small but gives it little functionality besides to send the signal. The antenna design was based on a reference design of the chip that uses a Balun filter to get the frequency of the signal to 2.45 GHz to send out the Bluetooth signal to the devices.

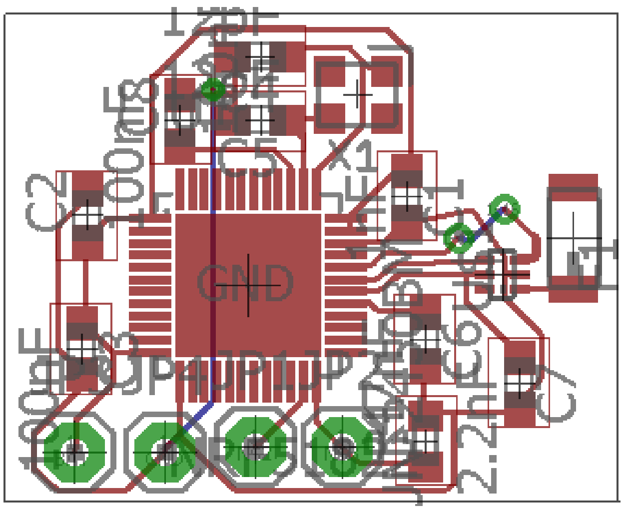


Fig. 8 PCB design for the first device, consisting mainly of a control unit and antenna for Bluetooth.

Device one works by having the micro controller automatically start to make a connection to the other devices as soon as it turns on. The device will be turned on a button being pressed and keeping the button held down to continue to establish the connection with the other devices. The device was designed in this way to help prevent accidental activation of the devices. If the device were to be accidentally tapped or dropped, the time of pressure being placed on the button would not be long enough for the device to turn on and maintain a connection long enough to send the activation signal.

IV. Device 2 Usability

The primary use for the second device is to receive the signal from the first device and then activate a MOSFET switch which will allow an on-board buzzer and LEDs to activate, which represents the self defense mechanisms that will be used by the company in the final design. The device is also designed with a charging circuit for the battery that will be used to keep the second device completely contained. This device is also required to be small, although the designs need for complexity and as it will eventually contain a mechanism for the actual self-defense capabilities that the company wanted to create. The PCB size for this device is 44.6 mm X 41.1 mm, with a smaller design with using both sides of the board also being developed to help maintain an even smaller size.

The design for the second device is split up into several various parts, with the primary control, the self-defense, and the charging circuit.

A.Primary control

The primary control of the device is designed nearly the same as the first device was designed. The biggest difference is that the primary control for the second device uses a voltage regulator as the power source being used has been tested to have a maximum voltage output of 4.2V although it is rated for only 3.7V. The regulator will be used to bring the voltage down to 3V which is safely in the range of the microcontroller voltage requirement of 1.8V to 3.6V.

B. Self-Defense

The self-defense portion of the circuit board uses a N-channel MOSFET that acts as a switch allowing current to pass from the battery to the components which will be acting as a stand-in for the self-defense mechanism. The switch is used rather than a direct connection to the microcontroller to ensure enough current to activate the components is achieved. The stand-in for the self-defense mechanism will be represented by a buzzer and an LED with a resistor to lower the current going to these devices. The resistor is placed in series compared to the other components as the buzzer operates at 2.5V rather than the 3V that will be coming from regulated battery.

C. Charging Circuit

The charging circuit for the second device is based on an Adafruit LiPo charging circuit that was redesigned to make the design smaller and to be attached in the device. The circuit uses a jumper to have a variable current for charging of the battery. This was left in as the battery can take the higher current for faster current when the device is in its final design, but for testing, the device will be using a slower current to ensure everything works without a hitch. A switch is placed in the device to allow to device to charge without being turned on without losing charge simultaneously. This also acts to save the battery life when the device will not be needed.

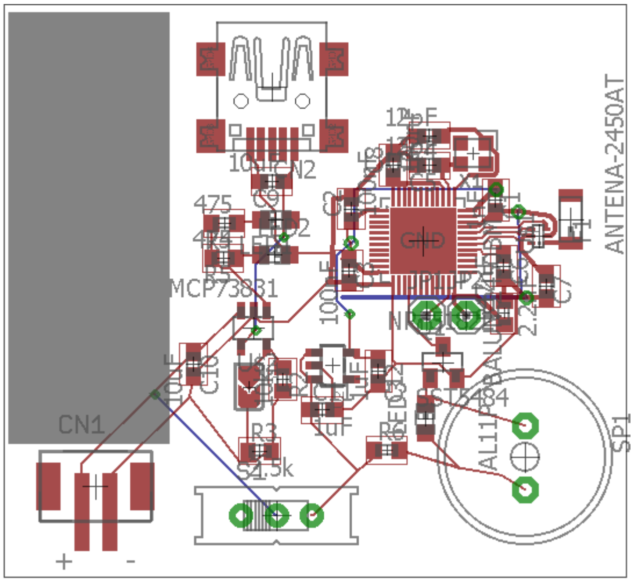


Fig. 10. PCB design for the second device, consisting of the charging circuit (Left) main control unit (Right) and the self-defense mechanism (Bottom)

The second device works by waiting for and receiving the signal from the first device through the microcontroller Bluetooth capabilities. When the signal is received, a pin of the microcontroller is turned on as an output. This signal activates the MOSFET switch which will turn on the self defense mechanism. When not in use, the device can be charged using a micro-usb charger, similar to most android phones.

MOSFET Characteristics:

The reason why the electrical engineers chose to implement a MOSFET transistor into the circuit as it acts like a voltage controlled switch. When device 2 is activated, the chip will output a voltage from its output pin which will allow the buzzer and led to turn on. But if the chip is not activated by device 1, the buzzer and the led will not turn on as there is no voltage coming out of the output pin.

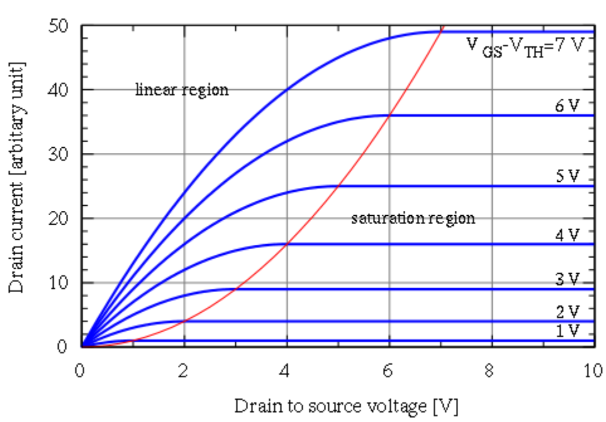


Fig. 11. Typical characteristics for MOSFET

As shown in the picture above, if the voltage across the gate and the source is higher than the threshold voltage, then current will be allowed to pass through the transistor.

Bluetooth:

For both of the devices and the phone application to be connected, the team decided on using Bluetooth. It would be used as a way to transmit the signal from device 1 to device 2 and the phone application. Both Device 2 and the Android application will be programmed to monitor the advertisement channel for when Device 1 is triggered.

V. Phone Application

This Android only application was built originally as a placeholder for an idea made by the team in Knightguard. There were three main purposes for building a smartphone application. The first was to provide an interface to input vital user information onto the database. This information includes name, hair and eye color, weight, height, and more. Once put in, the user will have to verify the account where a code will be sent from a no reply email. The second was to have a secondary emergency button in the event that Device 1 has an issue and it cannot send off the signal. The connection from the Device to the phone with the use of Bluetooth Low Energy. This will allow for Device 2 to still activate from the signal on the phone. The third was to upload the current location from the phone GPS into the web application. The GPS will keep track of the location and send continuous updates, which are reflected in the web application in a poll loop refreshing every five seconds.

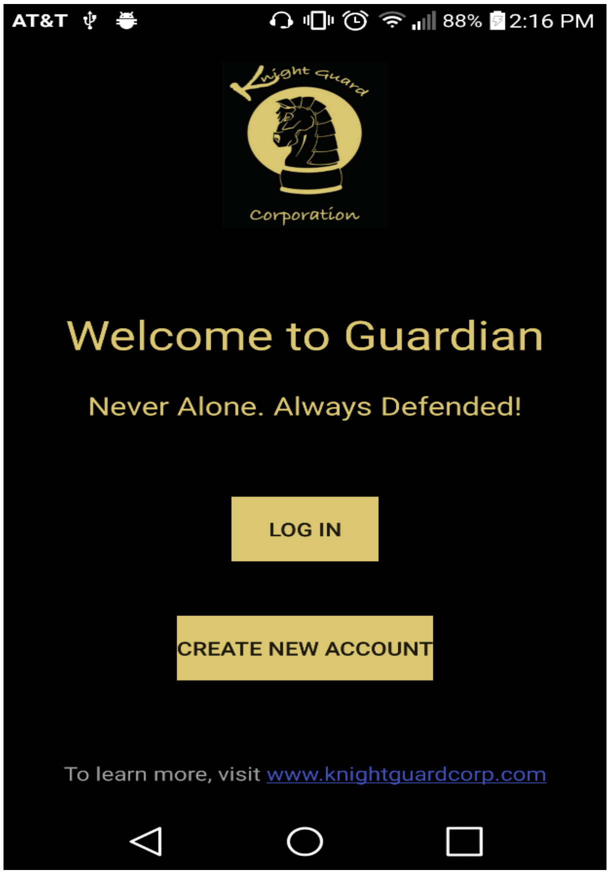


Fig. 12. Homepage for the App being created for the project that acts as a third device, giving GPS coordinates to the WebApp

VI. Database and Web Application

The main purpose of the database is to hold all the information regarding this project. Built in MySQL, the database holds the user information from registration, a log of alert system activation and associated GPS coordinates after either Device 1 or the emergency button on the phone is pressed. The data is accessible by authorized users of the web application, who are also presented with an alert console which displays any active user device or mobile application distress calls. The idle state of the application is shown below. During an alert, the left hand side of the screen is populated with all of the identifying user information pulled from the database. On the right, a shows a Google Maps instance shows the mobile application GPS location using a pushpin marker. Any changes in position reported by the mobile application will be fetched in a five-second loop and display as additional pushpins, with the latest update animated as a bouncing pin.

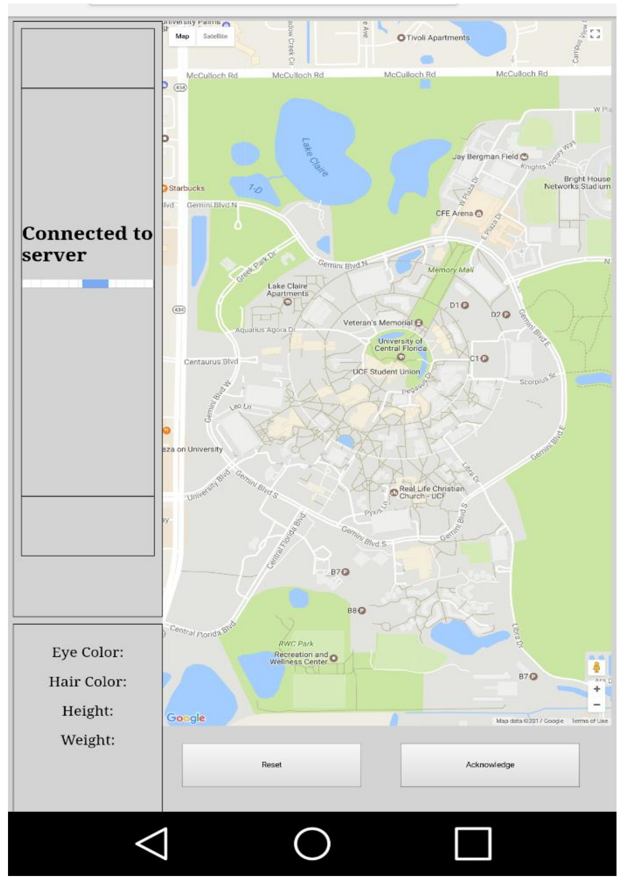


Fig. 13. Page view of the WebApp

VII. Comparative Devices

One of the primary reasons for making this device was to help protect people in case they were attacked, and to incapacitate the attacker as quickly as possible. Other devices for this do exist, but many of them are not efficient enough to ensure the safety of the victim and it specific instances will be unable to even be used before the assailant hinders the victim from even being able to grab the device.

One of the more common devices than people use in the case for self-defense are guns; more specifically, guns that easily be hidden in a purse of a small holster of the side of the user's hip. Guns receive a large amount of scrutiny as they always result in a large injury or even death when used in self-defense.

The problems with using a gun as a self-defense item falls around the time it takes to use the gun. If an attacker were to attack from behind or to attack in such a way that the victims' arms are immobilized, the gun will be unable to be used. Even when the attacker is seen before attacking, the victim would have to grab the gun, aim and shoot before the attack can happen.

Another popular self-defense item are knives as they can easily fit in your pocket. Knives are fairly lightweight and easy to conceal from an attacker. One of the main benefits to knives are that there are more widely accepted than guns, and can be carried in almost any place.

Knives, however, still cause serious to deadly injuries when used. Also, similarly to with a gun, when being attacked, the time it takes to remove a knife from its concealed spot, can be long enough for the attack to immobilize the victims arms, prohibiting them from using the weapon. http://www.asecurelife.com/self-defense-without-a-gun/

Stun weapons are used by many people because they have quick results, and for the majority of the time are non-lethal. These weapons typically will stop the target at least for a minimum of five seconds, giving the victim enough time to escape.

The positive to our device over others on the market are that it is non-lethal, acts quickly and can be use. Even when the arms of the victim are immobilized. This puts the device at a clear advantage compared to other, already popular devices.

VIII. Difficulties

Hardware:

Some of the difficulties the electrical engineering members had were that of size. One of the main constraints for this project was being able to fulfill all the requirements but device 1 had to be smaller than device 2 and device 2 had to be about the size of a large business card. Many design options were considered such as using both sides of the PCB to reduce size on device 1 but there were problems with that as well. Ultimately, the team had to start completely over due to errors in programing the chip.

3-D casing:

The first iteration of the casing for device 2 had clips attached to the side, that way the two pieces can clip together. This turned out to not be the best approach as the clips were flimsy and could break off easily. So, the second iteration used groves instead as this was easier to implement, and the same technique was used for device 1.

Software:

Connecting the web application to the database has been one of the main problems for the project.

Mobile phone application:

Some of the problems for this application include trying to get a connection between not only the app and the database, but also between the app and the Devices. Although a connection has been established between the database and the app, in regards of sending user information as well as current location, no connection has been made between the Devices, which is needed for the emergency button to be functional. One of the problems with this is trying to solve the problem of Bluetooth being a one to one connection whereas a network of connections is needed instead.

IX. Future plans of Knightguard and Guardian

As the project currently is, the PCBs are both are slightly larger than the final design will be when the project goes into full production. These were not created for the current design, so that the current design could be used for strictly testing purposes. The future design will utilize more layers to help eliminate space utilized by traces. The future of the project will also explore more ways to conceal the first device that may not require the device to be held in the hand at all.

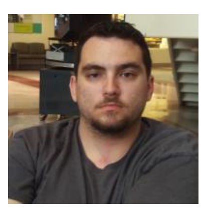
In the future, the company plans to put the device in full production and sell the devices as an affordable self-defense device. The hopes are to have the device affiliated with and monitored by local security firms as well as local authorities to have a direct viewing to the location of the crime, and be able to handle the situation before someone who can be attacked by the same person again. Another goal for the company is to be able to even distribute the device to authorities as a way to quickly incapacitate suspects to prevent the authorities from being having to use lethal force on the suspect, similar to the attacks that have caused large amount of controversies in the past couple years.

X. Conclusion

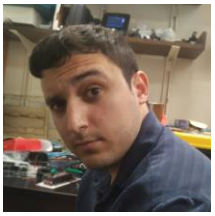
In conclusion, the team was successfully able to construct both device 1 and device 2 but with some minor adjustments. Due to the nature of circuitry, some complexity was removed from the final design to keep the size of the PCBs down. Along with this, both hardware casings are slightly larger than the original design due to the PCBs. As for the phone application, everything ran smoothly with only minor adjustments to help with the database.

Acknowledgements:

The Team:



Matthew Lucente is a senior in his fifth year of college, having change his major once, originally starting in Aerospace engineering, and will now be graduating with a Bachelor of Science in Electrical Engineering. Upon graduating, he will be starting a career at Lockheed Martin, as a testing and integration engineer. In the future he hopes to return for his Masters within the next five years.



Dominic Brumfield is a fifth-year senior who will obtain his Bachelor of Science degree in Electrical Engineering with a Minor in Mathematics in May 2017. His goals are to seek employment in communications or in the power systems industry as those are his interests.

Brandon Carruth is a senior in his fourth year who will obtain his Bachelor of Science degree in Computer Engineering at University of Central Florida at the end of the semester. His main interests include web/mobile development and design and will look for a position in this field of work.

Knightguard was a company founded by Mr. Tom Bland, after coming up with the idea for the Guardian project when he was worried about the what if with his daughter and wanting to design something her and others could use to protect themselves. The president of the company, Erik Olsen, has acted as a constant point of contact with the team, offering advise on how to proceed with the project, as well as helping when he could on fixing small problems on the software side of the project.

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